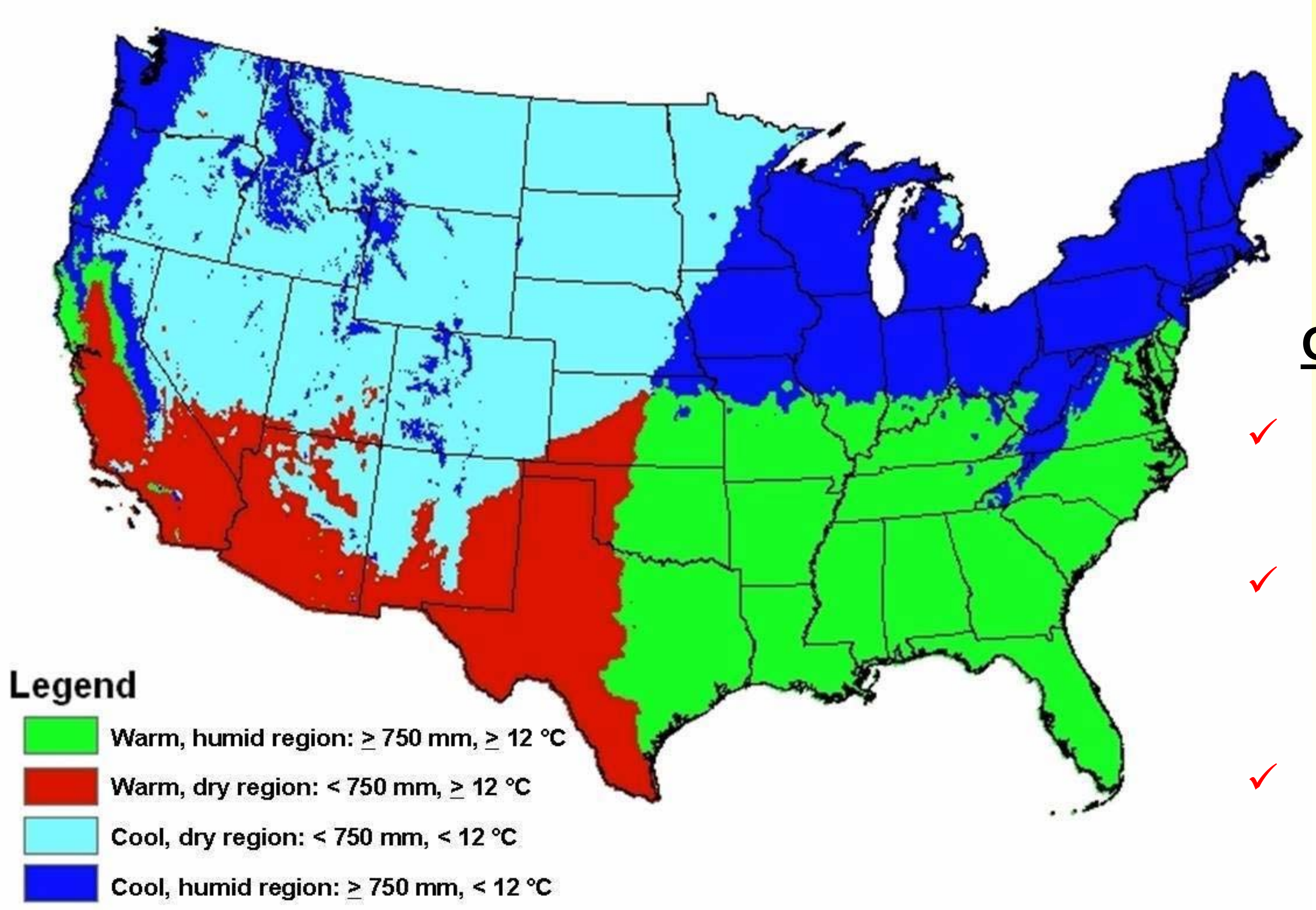
Soil Organic Carbon Sequestration in Pastures

Alan J. Franzluebbers

Ecologist

Watkinsville GA

Characteristics of Humid Grazing Lands

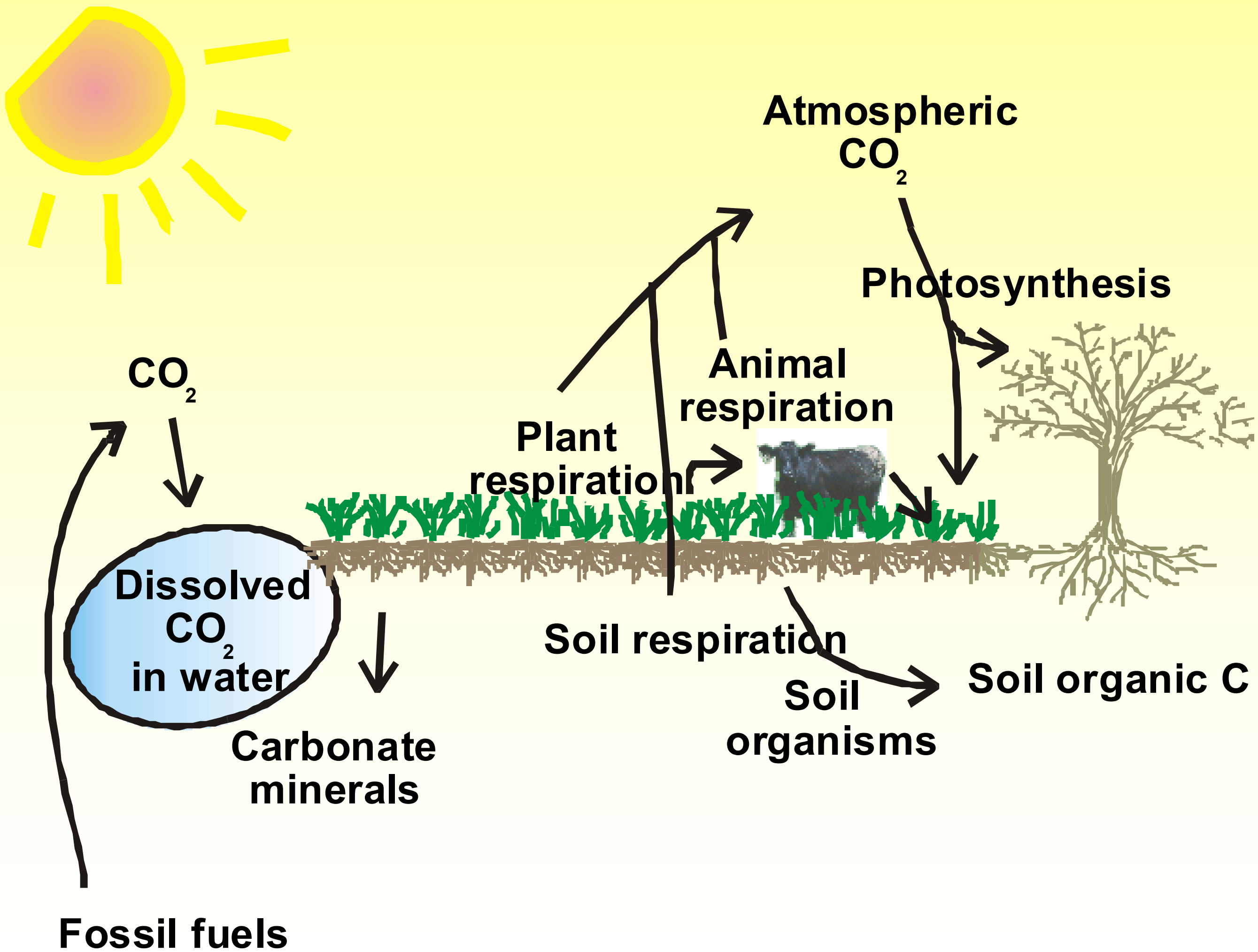


Generally

- ✓ Introduced plant species
- ✓ Responsive to management inputs
- ✓ High production potential

Soil Carbon Sequestration

Key Components



Processes

- Photosynthesis
- Biochemical transformations
- Harvest
- Respiration
  - Plant
  - Animal
  - Soil microbe
- Soil erosion
- Leaching

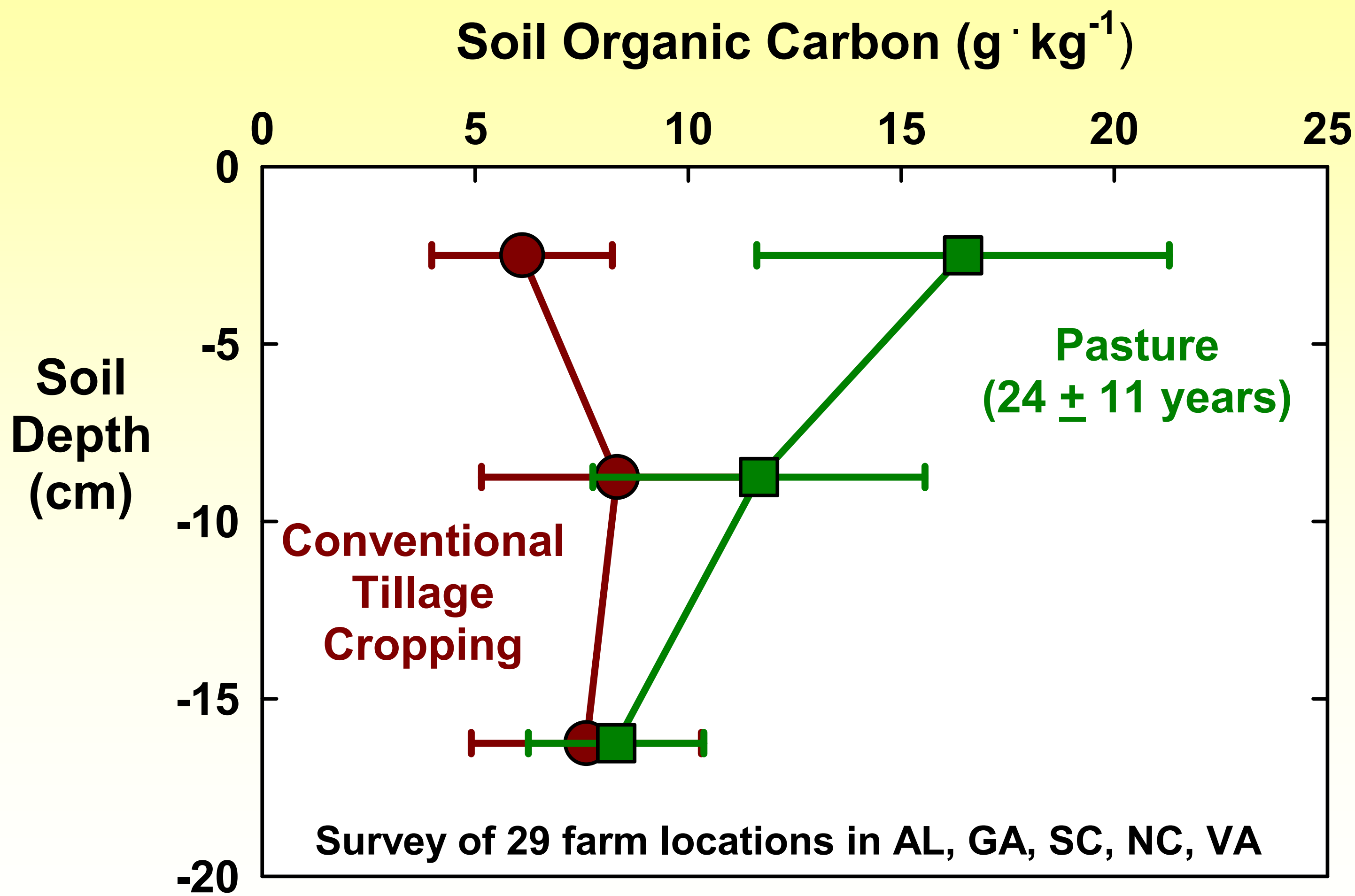
Potential of Pastures to Sequester C

Relative to Other Land Uses

Study	Depth (cm)	Forest	Grass	Crop	Significance Pr > F
		------------------ Mg ha^{-1} ------------------			
Eastern Texas Laws and Evans (1949), Potter et al. (1999)	30	--	88 $\pm$ 18	57 $\pm$ 8	<0.01
AL-AR-FL-GA-LA-MS-NC-SC-TX-VA McCracken (1959)	25	31 $\pm$ 12	31 $\pm$ 16	23 $\pm$ 15	0.04
Maryland Islam and Weil (2000)	15		32 $\pm$ 10	20 $\pm$ 7	0.01
Alabama Fesha et al. (2002), Torbert et al. (2004)	25 $\pm$ 6	60 $\pm$ 21	48 $\pm$ 26	34 $\pm$ 8	0.03
Mississippi, Georgia Rhoton and Tyler (1990), Franzluebbers et al. (2000)	25 $\pm$ 7	47 $\pm$ 2	38	22 $\pm$ 6	0.08
Mean	24 $\pm$ 6	49.9 a	47.4 a	31.1 b	

Franzluebbers (2005) Soil Till. Res. 83:120-147

Potential of Pastures to Sequester C
Relative to Cropping



Sequestration of SOC
(Mg ha^{-1} yr^{-1})

0.53 **

0.17 **

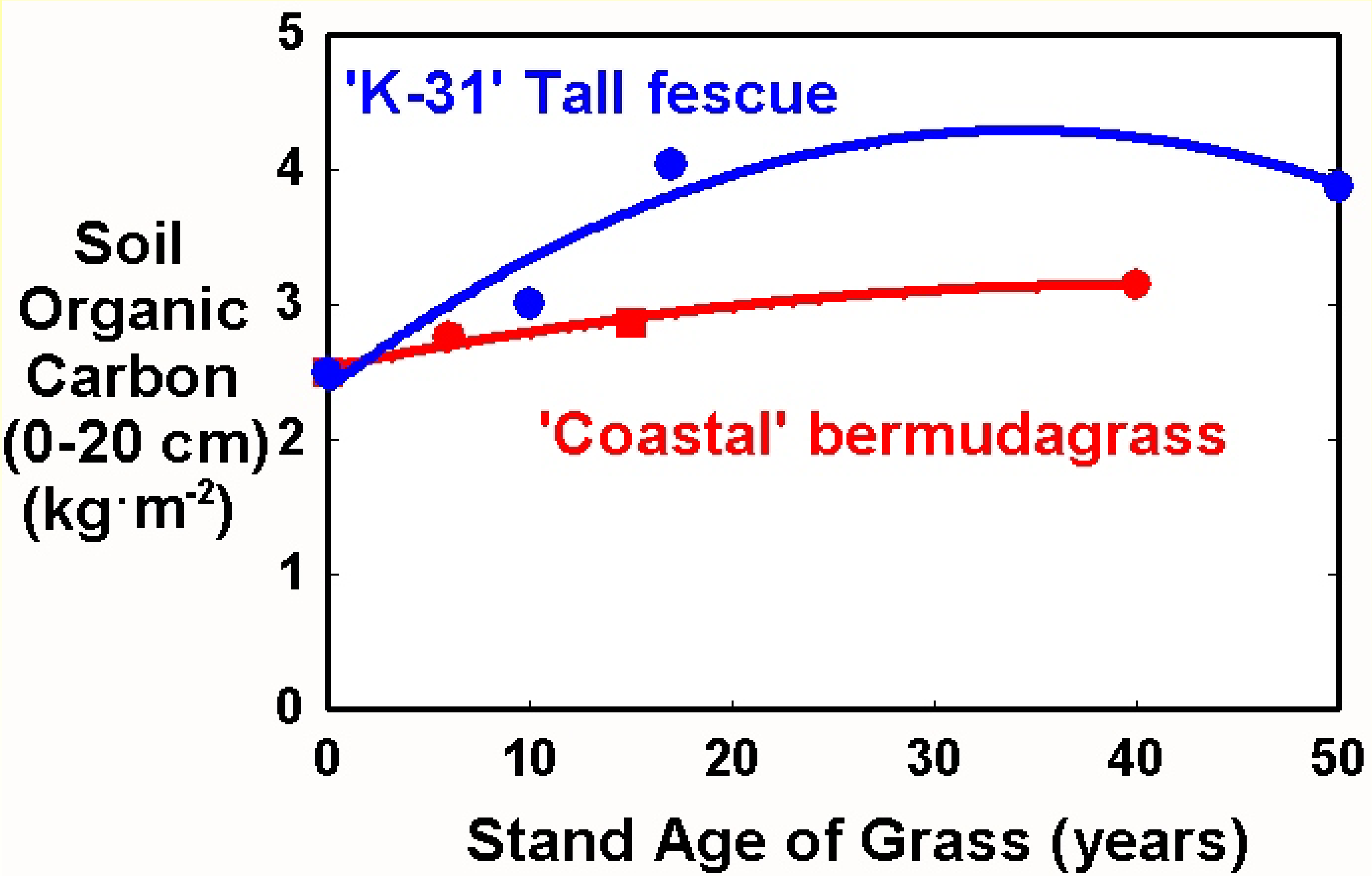
0.05 ns

<u>0-20 cm</u>
0.74 **

Causarano et al. (2008) Soil Sci. Soc. Am. J. 72:221-230

Management Effects: Duration

Cool- *vs* Warm- Season Grasses



Soil organic C sequestration rate during 25 years

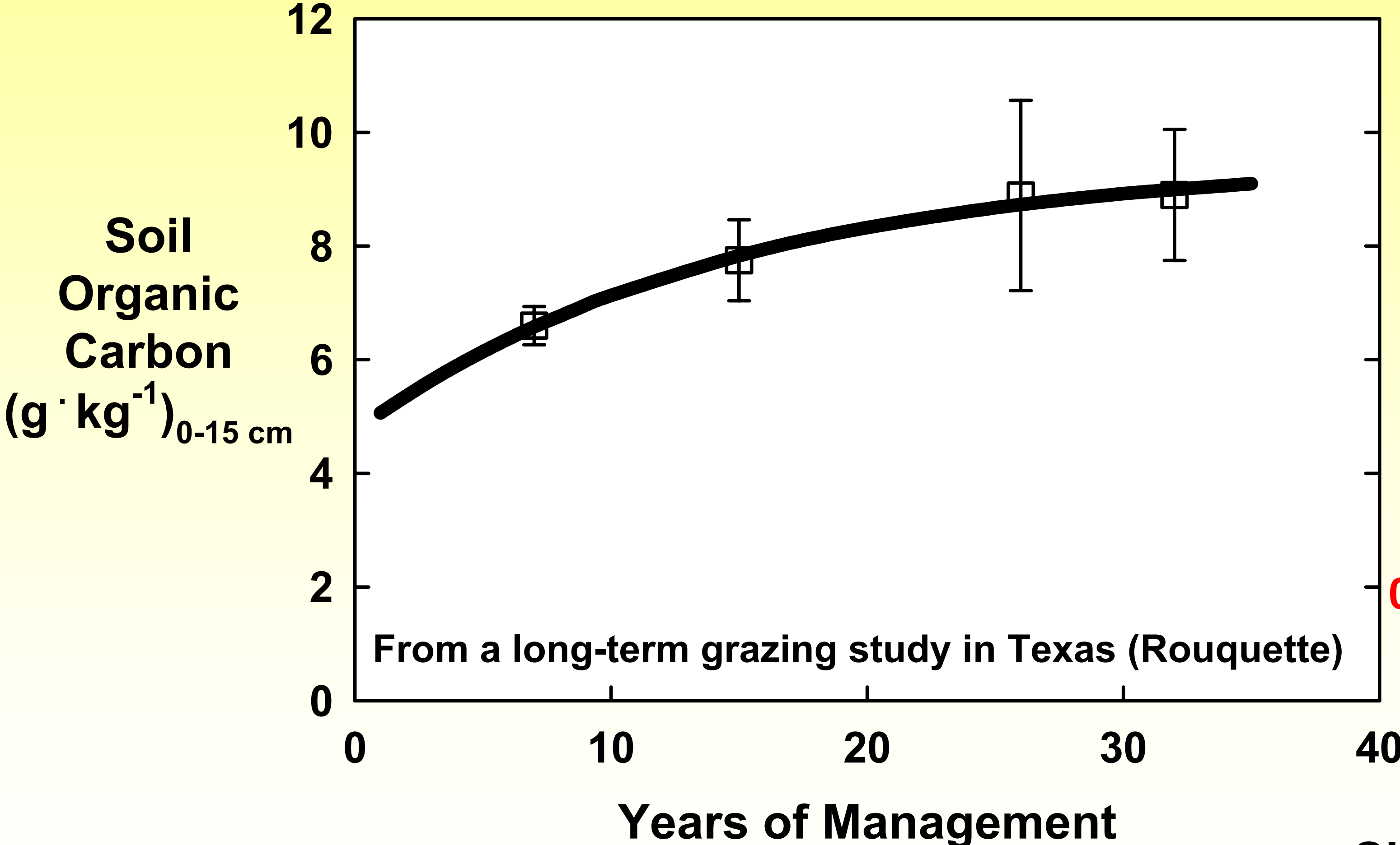
0.78 Mg ha^{-1} yr^{-1}

0.26 Mg ha^{-1} yr^{-1}

Different opportunities for growth during the year.

Franzluebbers et al. (2000) Soil Biol. Biochem. 32:469-478

Management Effects: Duration
Bermudagrass Pasture Age



Equivalent soil organic C sequestration rate during 25 years (assuming bulk density of 1.4 Mg m^{-3})

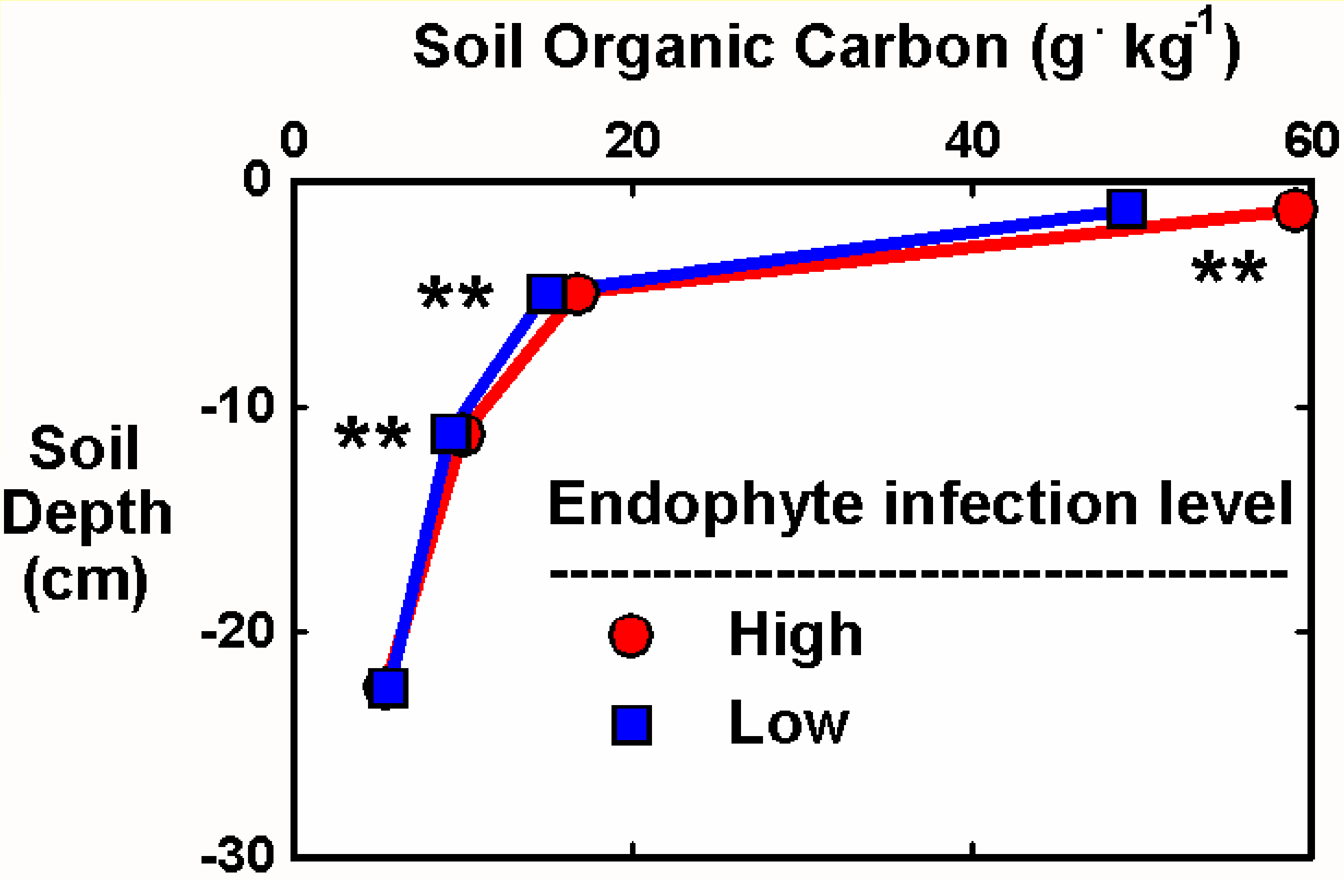
0.33 Mg ha^{-1} yr^{-1}

Similar rate to that observed in Watkinsville

Wright et al. (2004) Soil Biol. Biochem. 36:1809-1816

Management Effects: Forage Type

Tall Fescue—Endophyte Association



Specific Mineralization of SOC (mg CO_2-C g^{-1} SOC)

Low		High
98	**	78
43	**	38
26	*	23
16		16

Franzluebbers et al. (1999) Soil Sci. Soc. Am. J. 63:1687-1694

Management Effects: Forage Type

Tall Fescue—Endophyte Association

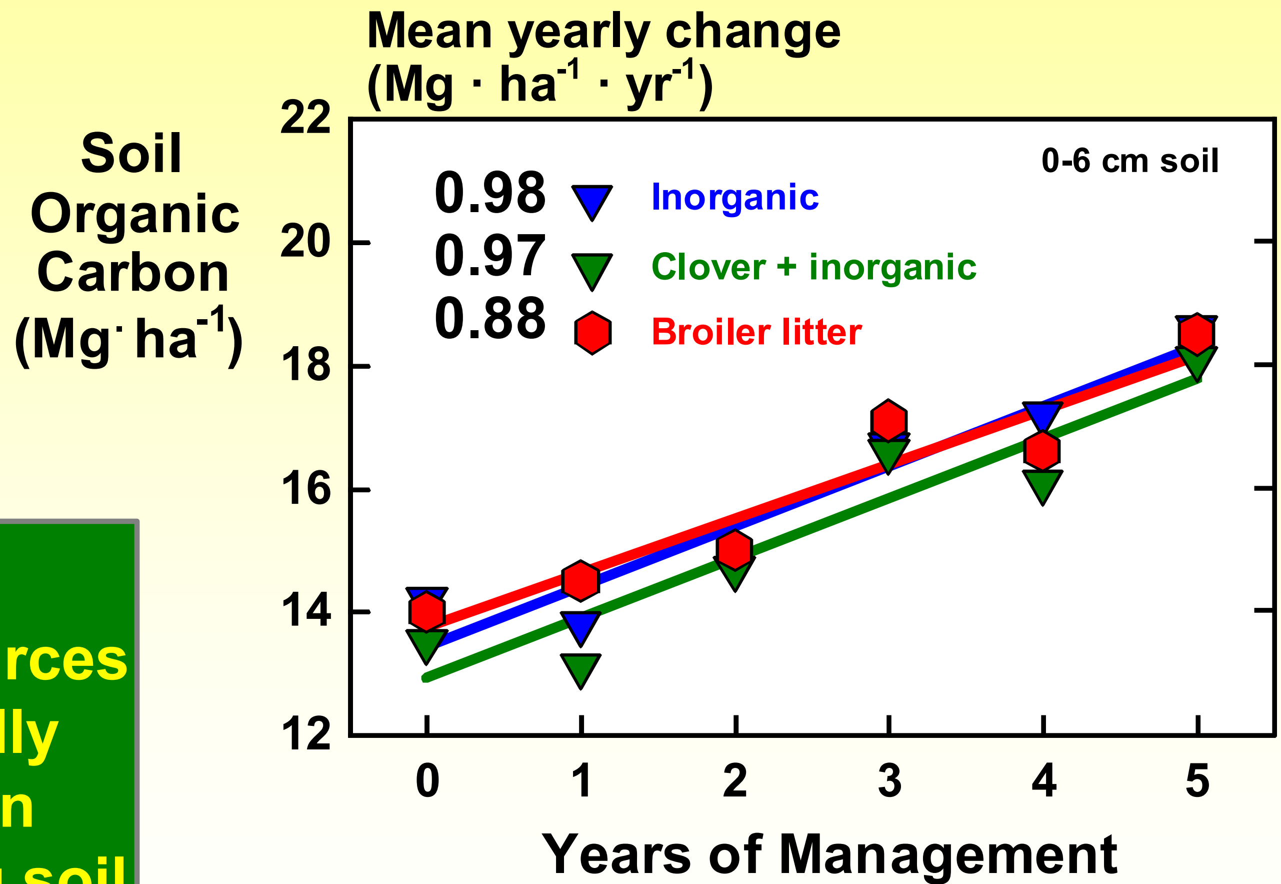
✓ **Isolation of endophyte effect within organic carbon fractions**

Soil pool	E-		E+	
Whole-soil organic C (Mg ha^{-1})	29.3	<	31.2	Accumulation of organic C
Macroaggregate C (Mg ha^{-1})	31.1	<<	33.6	In macroaggregate fraction
Particulate-to-total C (g g^{-1})	0.42	>	0.39	Per unit of total C, biologically active fractions depressed with endophyte
Microbial biomass-to-total C (mg g^{-1})	45	>	42	
Mineralizable-to-total C (mg g^{-1})	44		41	

Franzluebbers and Stuedemann (2005) Soil Sci. Soc. Am. J. 69:396-403

Management Effects: Fertilization

Inorganic *vs* Organic Source



Impact

Fertilizer sources were equally effective in sequestering soil organic C

Franzluebbers et al. (2001) Soil Sci. Soc. Am. J. 65:834-841

Management Effects: Fertilization
Inorganic *vs* Organic Source

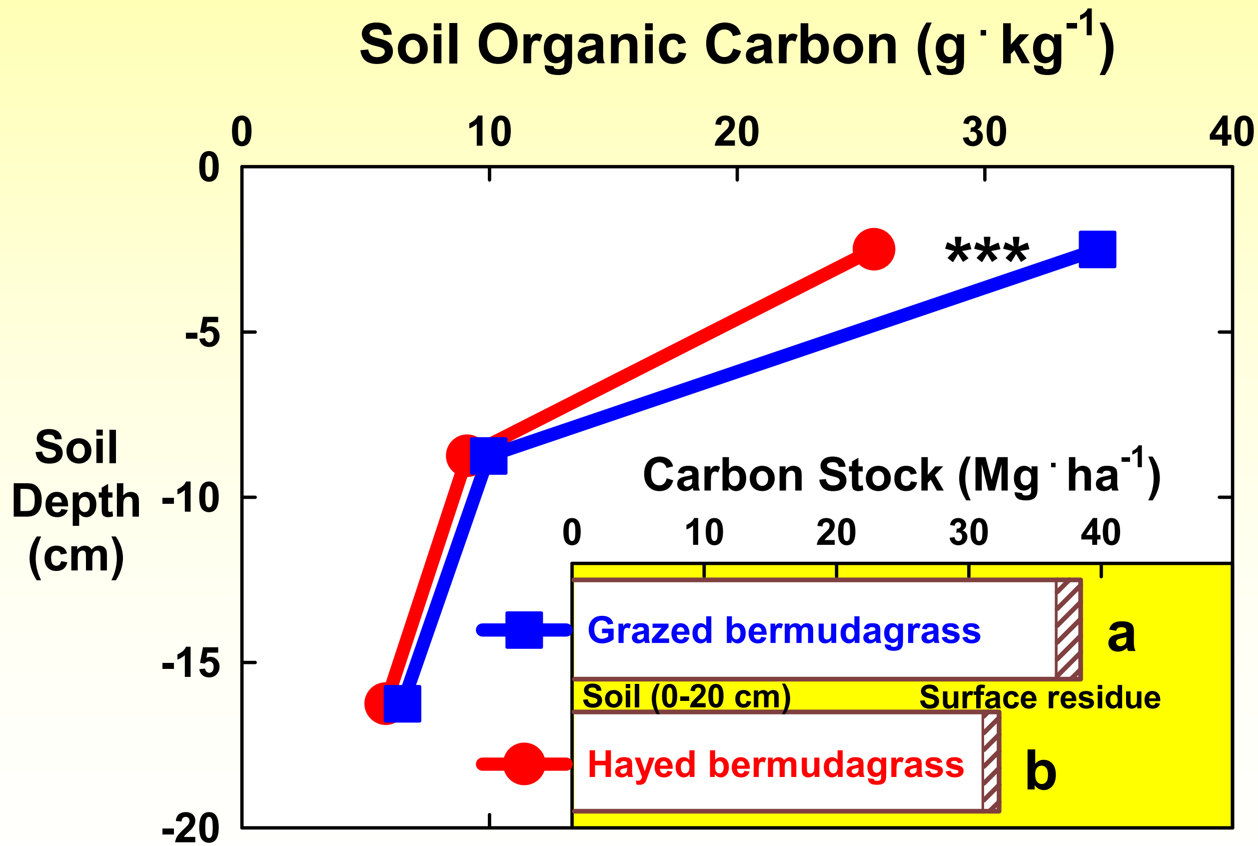
From a compilation of available literature around the world (Conant et al., 2001, Ecol. Appl. 11:343-355), SOC sequestration was compared between inorganic and organic fertilization.

Management	Rate of SOC Sequestration ($Mg\ ha^{-1}\ yr^{-1}$)
Inorganic fertilizer	0.29
Organic fertilizer	0.28

Management Effects: Forage Utilization

Grazed *vs* Hayed

✓ Long-term pasture survey (15- to 19-year old fields, 3 each)



Surface residue
1.2
1.8

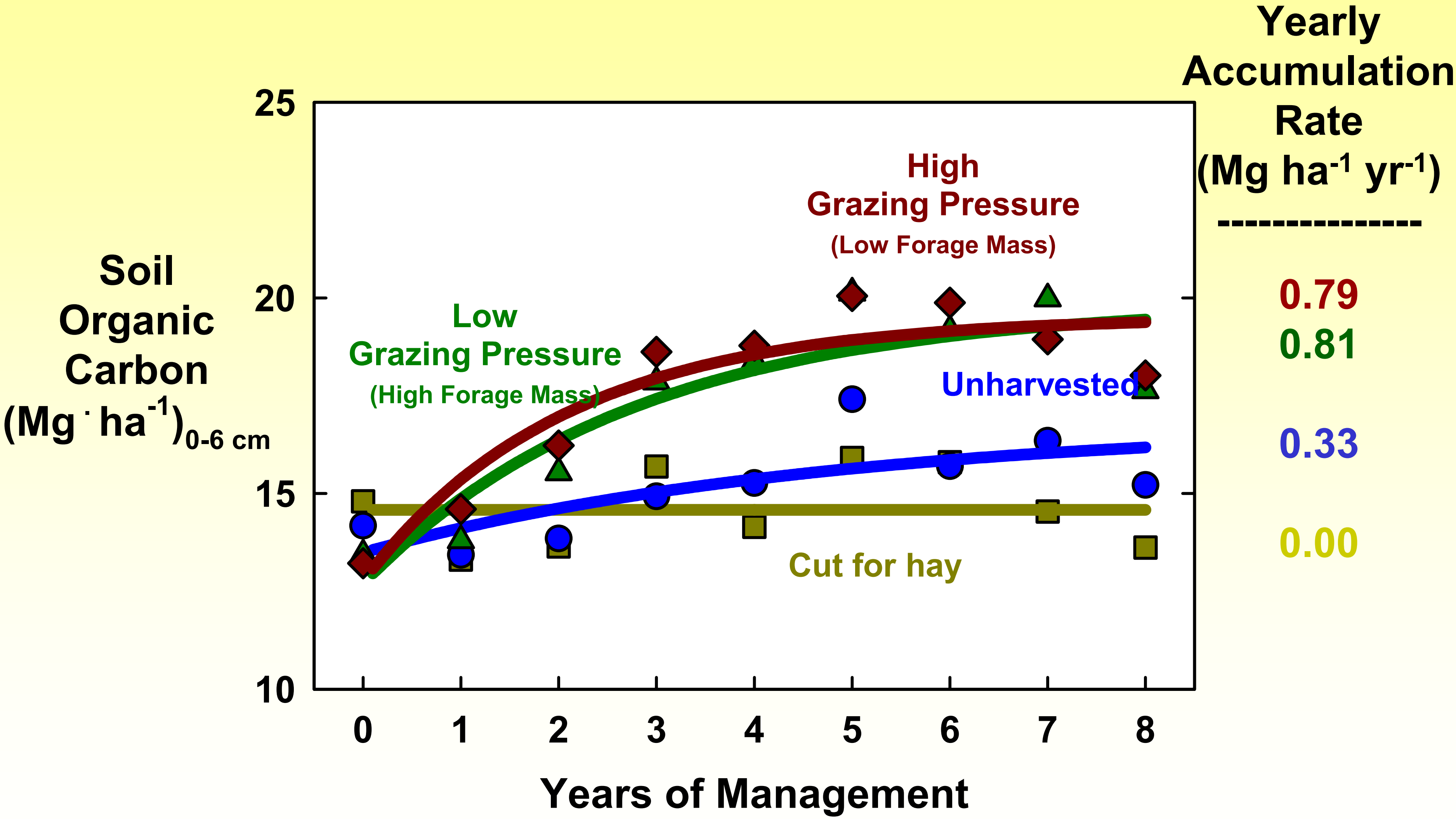
Soil (0-20 cm)
31.1
38.0

Difference
7.5
Mg ha^{-1}

Franzluebbers et al. (2000) Soil Biol. Biochem. 32:469-478.

Management Effects: Forage Utilization

Grazed *vs* Ungrazed

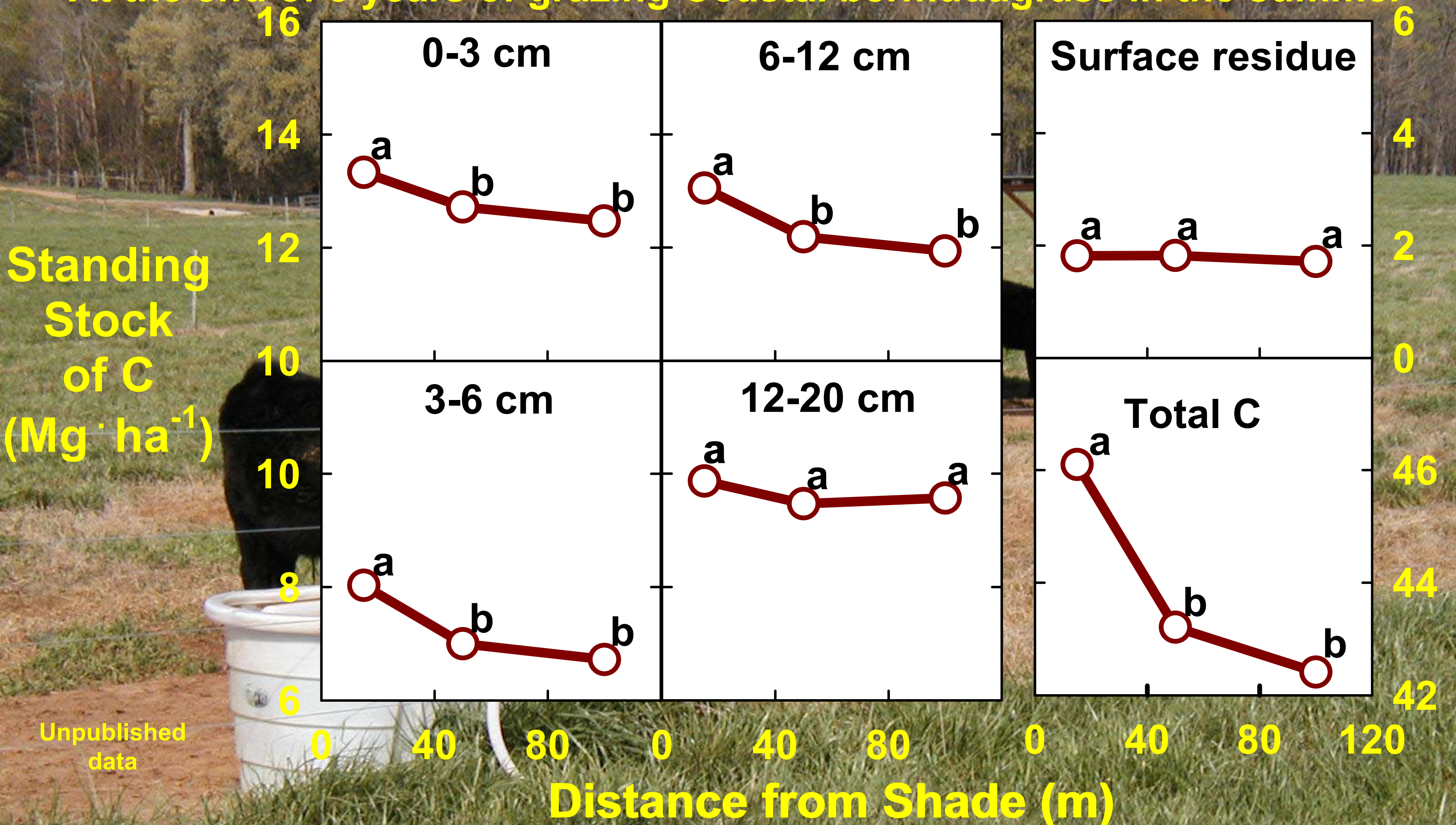


Franzluebbers et al. (2001) Soil Sci. Soc. Am. J. 65: 834-841 and unpublished data

Management Effects: Forage Utilization

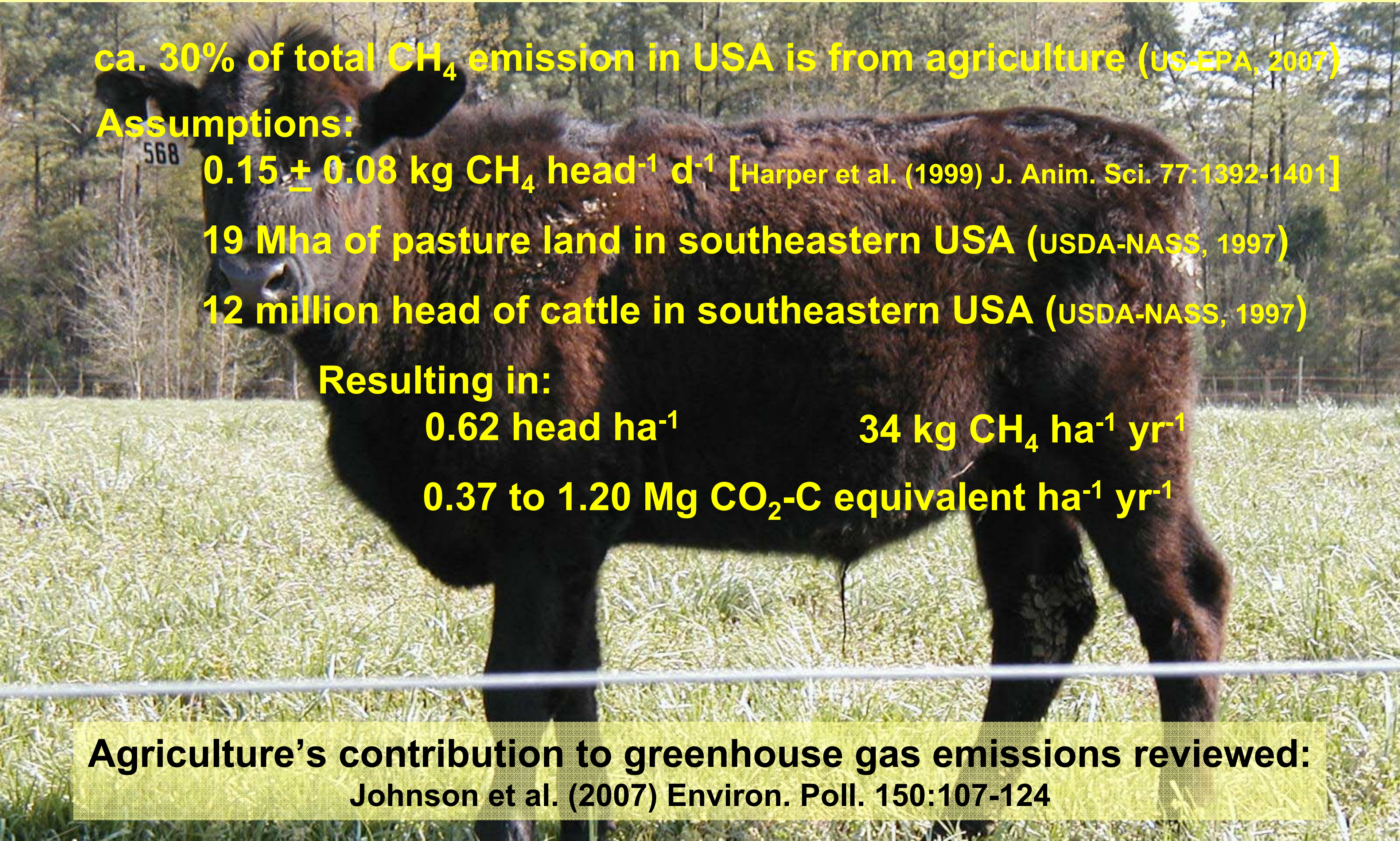
Animal Behavior

At the end of 5 years of grazing Coastal bermudagrass in the summer



Pasture System Effects

Methane Emission



ca. 30% of total CH_4 emission in USA is from agriculture (US-EPA, 2007)

Assumptions:

0.15 ± 0.08 kg CH_4 head^{-1} d^{-1} [Harper et al. (1999) J. Anim. Sci. 77:1392-1401]

19 Mha of pasture land in southeastern USA (USDA-NASS, 1997)

12 million head of cattle in southeastern USA (USDA-NASS, 1997)

Resulting in:

0.62 head ha^{-1}

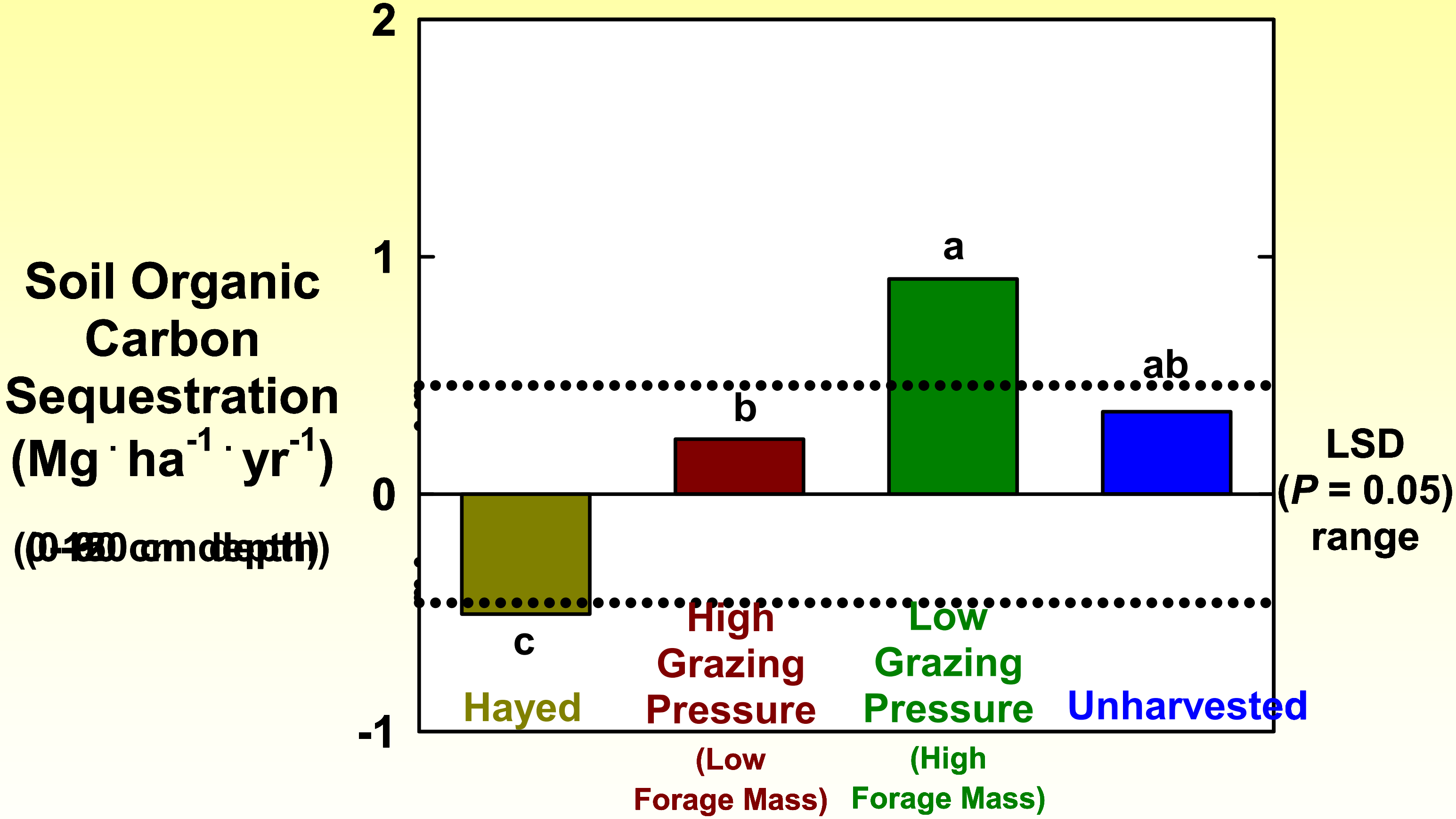
34 kg CH_4 ha^{-1} yr^{-1}

0.37 to 1.20 Mg CO_2-C equivalent ha^{-1} yr^{-1}

Agriculture's contribution to greenhouse gas emissions reviewed:

Johnson et al. (2007) Environ. Poll. 150:107-124

Soil Sampling Effects
Soil Depth Variation



Linear regression estimates of soil organic C sequestration sampled at 0, 5, and 12 years of management

Franzluebbers and Stuedemann (unpublished data)

Summary

- ✓ Establishment of perennial grass pastures can sequester soil organic C at rates of

  0.25 to 1.0 Mg C ha^{-1} yr^{-1}

- ✓ Soil organic C sequestration rate can be affected by:
  - Forage type
  - Fertilization
  - Forage utilization
  - Animal behavior
  - Soil sampling depth

Conclusions

- ✓ **Sequestration of SOC under grassland management systems is significant**
  - **Balance needed with ill-defined CH_4 emission**

- ✓ **Rate of SOC sequestration under the wide diversity of pasture conditions still largely unknown**
  - **Variations in management, climate, soils, etc.**

- ✓ **Greater collaboration is needed to efficiently utilize limited resources and better understand the impacts of diverse conditions on SOC sequestration**
  - **Among plant, animal, soil, and water science disciplines**
  - **Long-term field studies need conceptual and financial support**